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ON A THEROPOD DINOSAUR (ABELISAURIA) FROM THE CONTINENTAL CRETACEOUS OF BRAZIL[1]

(With 4 figures)

ALEXANDER W. A. KELLNER[2]
DIOGENES DE ALMEIDA CAMPOS[3]

ABSTRACT: A new theropod (*Pycnonemosaurus nevesi* gen.nov., sp.nov.) is described, based on five incomplete teeth, parts of seven caudal vertebrae, a right pubis (lacking the proximal part), a right tibia, and the distal articulation of the right fibula. The specimen (DGM 859-R) was found in a red conglomeratic sandstone at the locality Fazenda Roncador (Mato Grosso), which is referred to the Upper Cretaceous Bauru Group. *Pycnonemosaurus nevesi* is classified in the Abelisauria because of the expanded distal ends of the transverse processes in some (but not all) caudal vertebrae. It differs from all other members of this clade by its small pubic foot and hatchet-shaped cnemial crest of the tibia. This new taxon confirms the presence of abelisaurs in the continental Upper Cretaceous strata of Brazil.

Key words: Dinosauria, Theropoda, Cretáceo, Mato Grosso, Brazil.

RESUMO: Sobre um novo dinossauro (Abelisauria) do Cretáceo continental do Brasil.

Um novo terópode (*Pycnonemosaurus nevesi* gen.nov., sp.nov.) é descrito baseado em cinco dentes incompletos, partes de sete vértebras caudais, pubis direito (sem a parte proximal), tíbia direita, articulação distal da fíbula direita. Esse espécime (DGM 859-R) foi encontrado em um conglomerado arenítico avermelhado na localidade Fazenda Roncador (Mato Grosso), referida ao Grupo Bauru (Cretáceo Superior). *Pycnonemosaurus nevesi* é classificado dentro de Abelisauria devido à presença de algumas vértebras caudais (não todas) com a parte distal do processo transverso expandido. Essa espécie se diferencia dos demais membros deste clado principalmente pelo processo distal do púbis pequeno e pela crista cnemial da tíbia em forma de machado. Esse novo táxon confirma a presença de abelissauros nos depósitos continentais do Cretáceo Superior do Brasil.

Palavras-chave: Dinosauria, Theropoda, Cretáceo, Mato Grosso, Brasil.

INTRODUCTION

According to the catalog of the Museu de Ciências da Terra (DNPM, Rio de Janeiro), during 1952/1953 Llewellyn Ivor Price went to the farm "Roncador" in the State of Mato Grosso and collected several dinosaur bones. The remains were found by the owner of the farm, Max de Barros Erhart, and his workers at a site near Paulo Creek. The most important specimen was an incomplete skeleton of a large theropod (DGM 859-R), which was found associated with several isolated sauropod bones, including procoelic caudals referable to the Titanosauridae. The theropod material, briefly mentioned before (BERTINI, 1996; KELLNER & CAMPOS, 2000a,b), represents a new abelisaur taxon that is described here and compared to the other members of this clade, particularly with *Carnotaurus sastrei* Bonaparte, 1985, *Xenotarsosaurus bonapartei* Martínez, Giménez, Rodriguéz & Bochatey, 1986; *Llokelesia aguadagrandensis* Coria & Salgado, 1998; and *Aucasaurus garridoi* Coria, Chiappe & Dingus, 2002.

SYSTEMATIC PALEONTOLOGY

Theropoda Marsh, 1881
Abelisauria Novas, 1992
Abelisauridae Bonaparte & Novas, 1985
Pycnonemosaurus gen.nov.

Diagnosis – Abelisaur with the following autapomorphies: tibia with hatchet-shaped cnemial crest; pubis with a relatively small pubic foot; caudal vertebrae showing moderate distal expansion of the transverse processes.

Type species – *Pycnonemosaurus nevesi* sp.nov.

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[1] Received on July 31, 2001. Accepted on March 28, 2002.

[2] Fellow of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

[3] Museu de Ciências da Terra, Departamento Nacional da Produção Mineral (MCT/DNPM-RJ). Av. Pasteur 404, Urca, 22290-240. Rio de Janeiro, RJ, Brasil. Fellow of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

Etymology – From the Greek - *pycnós* - meaning dense + *nêmos* - meaning pasture, wood + *saûrus* - meaning reptile or lizard; in allusion to Mato Grosso, where the specimen was found.

Pycnonemosaurus nevesi sp.nov.
Figs.1-4

Diagnosis – the same as for the genus.

Etymology – in honor of Dr. Iedo Batista Neves (deceased in 2000), who encouraged paleontological studies, particularly of A.W.A.Kellner.

Holotype – incomplete skeleton (DGM 859-R) housed at the Museu de Ciências da Terra (MCT - DNPM, Rio de Janeiro), composed of five incomplete teeth, parts of seven caudal vertebrae (two incomplete, four caudal centra, one transverse process), several rib fragments, right pubis (lacking proximal part), right tibia, distal articulation of the right fibula, and several unidentified incomplete bones. All have been found associated and are regarded as belonging to the same individual.

Locality – the material was recovered from the Fazenda Roncador, close to Paulo Creek, about 1km S/SW of the main building of this farm, MATO GROSSO, BRAZIL. All were preserved in a red conglomeratic sandstone, which is referred to the Bauru Group. The age of the outcrops of the upper portion of this stratigraphic unit (Adamantina and Marília formations) in São Paulo (based on microfossils) is disputed, with some authors suggesting a Turonian to Maastrichtian age (DIAS-BRITO *et al.*, 2001) while others restrict it to the Campanian-Maastrichtian (GOBBO, PETRI & BERTINI, 1999).

DESCRIPTION AND COMPARISON

No elements of this partial skeleton are well preserved. The bone surface tends to be abraded, indicating that most elements were at least partially exposed at the outcrop before being collected. Some of the more incomplete and fragmentary material is still partially covered by red conglomeratic sandstone and can not be identified at this time.

TEETH (not figured). The five available teeth are incomplete, presenting only the dentine, and just one has some of the enamel preserved. The latter is the most complete (preserved length: 84.3mm; crown: 49.7mm) and showed what appeared to be wrinkles on the enamel (KELLNER & CAMPOS, 2000a), but further preparation indicated that this was an artifact. The anterior carina and a small part of the posterior carina are preserved, where denticles are positioned at an angle relative to the long axis of the tooth. There are 1.8 (on top) to 2.0 (on base) denticles per mm. The blood grooves extend from between the bases of adjacent denticles onto the surface of the crown, and are curved towards the base of the tooth. A detailed description (with illustrations) of this material will be presented elsewhere.

So far, no teeth have been described from other abelisaurs: the type of *Abelisaurus* lacks the dentition (BONAPARTE & NOVAS, 1985); *Carnotaurus sastrei* teeth are broken and partially covered by resin/plaster; the original material of *Indosuchus* is lost (CHATTERJEE, 1978), and no detailed description of the teeth of *Majungatholus* and *Aucasaurus* is available (SAMPSON *et al.*, 1998; CORIA, CHIAPPE & DINGUS, 2002).

CAUDAL VERTEBRAE (Fig.1). Remains of seven caudals are preserved: one left transverse process, four centra, and two fairly complete vertebrae lacking parts of the neural arches and the zygapophyses, all from the anterior portion of the tail. Based on their sizes (particularly the height of the centrum), the isolated centra occupied more proximal positions in the caudal sequence compared to the two complete ones, which are smaller (length of the centrum varies from 149 to 152mm). Whether or not the comparatively large transverse process and the largest centrum formed part of a same vertebra cannot be established at this point. Except for the second and third preserved vertebrae, none seem to have been articulated with each other. The dorsal surface of the four isolated centra clearly shows the contact surface with the neural arch, indicating that they were unfused and separated from each other before burial. All centra are spool-shaped, laterally compressed and amphicoelic, with the anterior articular surface more deeply concave than the posterior one. The ventral margin of each centrum is concave and the posterior end of the vertebra expands to project postero-ventrally. Small nutrient foramina pierce the lateral sides of the centra close to the contact with the neural arch. In ventral view, the middle part of the ventral surface of the centrum has a flat or slightly concave surface, which curves anteroposteriorly. The last three preserved caudals have paired depressions for the chevrons at the posterior end; none was observed at the anterior border.

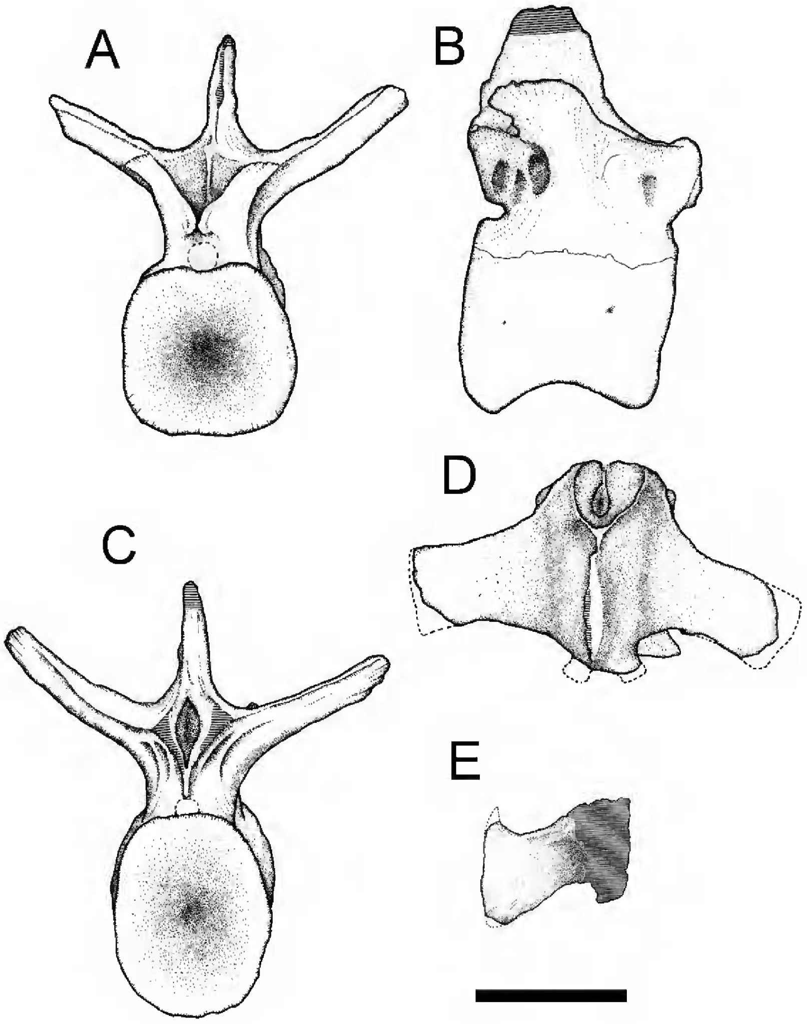

Fig.1- *Pycnonemosaurus nevesi* sp.nov. (DGM 859-R), caudal vertebra in anterior (A), right lateral (B), posterior (C), and dorsal (D) view; isolated caudal transverse process (E) in dorsal view - note the expanded distal end. Scale bar: 100mm.

The neural arch can only be observed in two vertebrae. In both the sutures with the centrum are partly obliterated, indicating that fusion was in progress. The neural spine is incomplete in both, but based on the preserved parts is directed dorsoposteriorly. Hyposphene and hypanthrum are present. Three depressions can be observed on the lateral side: near the prezygaphophyses, at the lateroposterior base of the transverse process, and on the lateral side of the hyposphene (ventral to the postzygapophyses). Transverse processes are anteroposteriorly wide, directed dorsolaterally (in proximal view) and posteriorly (in dorsal view), and are slightly expanded distally. The isolated transverse process that belongs to a much larger element shows the distal end more anteroposteriorly expanded, and had an anterior projection (incomplete in this specimen).

Other abelisaurs from which caudal vertebrae are described are *Carnotaurus sastrei*, *Llokelesia aguadagrandensis* and *Aucasaurus garridoi* (one specimen of *Majungatholus* has part of the tail preserved, but it was not studied so far [SAMPSON *et al.*, 1998]). In *Carnotaurus*, the first six caudals were found articulated but preserved to different degrees. The distal end of the transverse processes are expanded, but become less pronounced in subsequent caudals. Although the exact positions in the tail of the preserved caudals of *Pycnonemosaurus nevesi* are not known, direct comparisons indicate that the expansion of the transverse processes is not developed to the same degree as in *Carnotaurus*. In the last preserved caudals, the transverse processes are hardly expanded at all. The centra of *Pycnonemosaurus nevesi* tend to be taller than wide, while in *Carnotaurus* they tend to be more circular.

The caudals of *Llokelesia* belong to the mid-distal section of the tail and have the transverse processes more horizontal compared to *Pycnonemosaurus* (and *Carnotaurus*), with the distal end of the transverse processes more expanded. The preserved caudal centra of *Llokelesia* are comparatively broader than the ones of *Pycnonemosaurus*, but this could be related to the different positions that those elements occupy in the tail.

The most complete published caudal series of an abelisaur belongs to *Aucasaurus* and comprises the first 13 elements of the tail. The main difference with *Pycnonemosaurus* is the awl-like projections of the transverse processes present in all caudals of *Aucasaurus*.

Lastly, some authors consider *Ligabueino andesi* Bonaparte, 1996 as a member of the Abelisauria (*e.g.*, CORIA & SALGADO, 1998), of which only one caudal is known. This element is apparently from the posterior portion of the tail. It is more elongated anteroposteriorly and lacks a distal expansion on the transverse processes being therefore very different from *Pycnonemosaurus nevesi* and all other abelisaurs for which caudals are known.

PUBIS (Fig.2A, B). Only the right pubis is preserved, lacking the proximal part (preserved length: 778mm). It is an elongate and slender bone. The distal part of the shaft is dorsoventrally flattened, turning more rounded proximally. In lateral view, this bone is essentially straight. Medially it has a well developed crest that likely contacted the opposite pubis. This crest ends proximal to the anteroventral tip of the pubic foot. Although the exact extension of the pubic symphysis is not known, it did not extend to the anteroventral tip of the pubis. The pubic foot is comparatively small (243mm), less than 30 % of the preserved pubic length. The anterior part (anterior to the intersection of the central axis of the pubic shaft and the longitudinal axis of the pubic foot) is only a little smaller (110mm) than the posterior part (133mm). The latter is laterally compressed and does not project very far posteriorly. On the anterolateral surface, the pubic foot has a protuberance for muscle attachment.

The only other abelisaur in which the pubis is described is *Carnotaurus* (BONAPARTE, NOVAS & CORIA, 1990). In *Pycnonemosaurus* this bone differs mainly by the smaller size of the pubic foot (particularly the posterior expansion) and by the presence of a protuberance on the anterolateral surface of the pubic foot. Apparently also *Aucasaurus* has a comparatively larger pubic foot (see CORIA, CHIAPPE & DINGUS, 2002: fig.1).

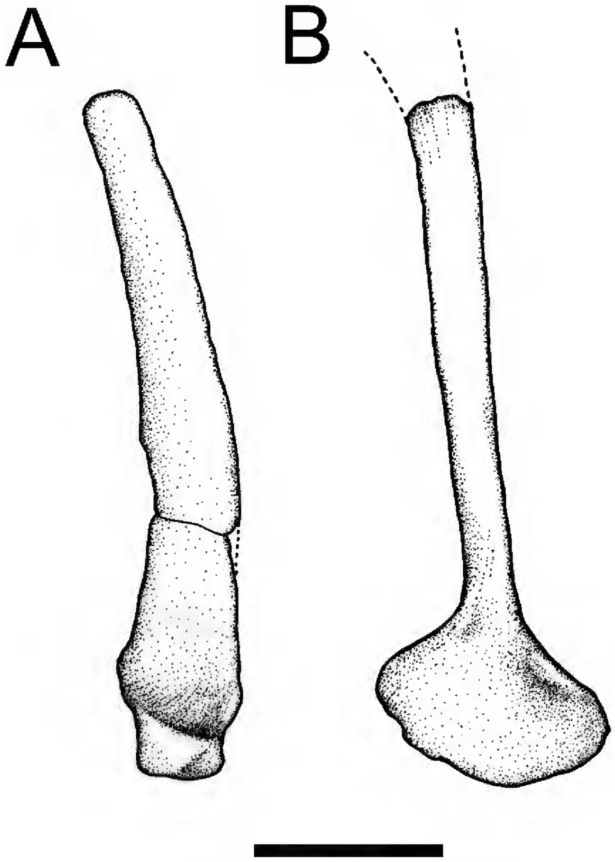

Fig.2- *Pycnonemosaurus nevesi* sp.nov. (DGM 859-R), right pubis (incomplete) in anterior (A) and lateral (B) views. Scale bar: 200mm.

TIBIA (Fig.3A-D). The right tibia of *Pycnonemosaurus nevesi* is fairly complete, although several parts of the shaft have been restored by plaster (possibly during the collection of this specimen). The length of the shaft is 782mm, but the maximum length of this bone, including the cnemial crest, is ca. 845mm. The shaft tends to be straight and has an oval transverse section, being compressed anteroposteriorly (middle portion: 124 x 99mm; minimum circumference: 367mm). The proximal articulation is incomplete and lacks part of the medial surface. The preserved part is 145mm wide (reconstructed mediolaterally: ca. 155mm) and, considering the cnemial crest, 35mm long (anteroposteriorly). The separation between lateral and medial portions of the proximal articulation is made by a shallow intercondylar groove. Between the fibular articulation and the cnemial crest there is a deep *incisura tibialis*. The cnemial crest is very pronounced and projects anterodorsally. Its distal portion is expanded dorsoventrally (195mm) with a constricted neck (150mm), giving it a hatchet shape (Fig.3B,D). The ventral border of the cnemial crest is slightly warped laterally. The fibular crest is not completely preserved in this specimen; the area right behind it has a well developed depression. The distal articulation is 235mm wide, with its largest anteroposterior length 129mm. A small portion of the medial margin is not preserved. The ventral margin (contact with the astragalus) is inclined lateromedially at an angle of 20-25° to the horizontal surface, with the deepest point at the lateral edge. The contact surface for the astragalus is indicated by a triangular depression on the anterior surface, which raises approximately 160mm up the tibia, roughly 19% of the total length of this bone.

Among abelisaurs, the tibia is only known in *Carnotaurus* (proximal part), *Xenotarsosaurus* (complete) and *Aucasaurus*. *Pycnonemosaurus* differs by having the distal end of the cnemial crest hatchet-shaped in side view. In *Aucasaurus*, the cnemial crest is subquadrangular (CORIA, CHIAPPE & DINGUS, 2002). In all four, the cnemial crest is directed anterodorsally. Based on the articulation surface for the astragalus, the astragalar ascending process in *Pycnonemosaurus* is comparatively wider, extending more laterally than in *Xenotarsosaurus*.

Another theropod was recently described in Argentina based on a hindlimb that shows some affinities with *Pycnonemosaurus nevesi*. This species, named *Quilmesaurus curriei* Coria, 2001, was found in the Allen Formation (Campanian - Maastrichtian), Rio Negro. It is based on the distal half of the femur and a complete tibia that showed no particular affinities within Theropoda (CORIA, 2001). The material is not well preserved and suffered from a great deal of compression. The cnemial crest of the tibia is distally expanded, but differs from *Pycnonemosaurus nevesi* by being hook-shaped. Nevertheless this similarity suggests that *Quilmesaurus curriei* might be also a member of the Abelisauria.

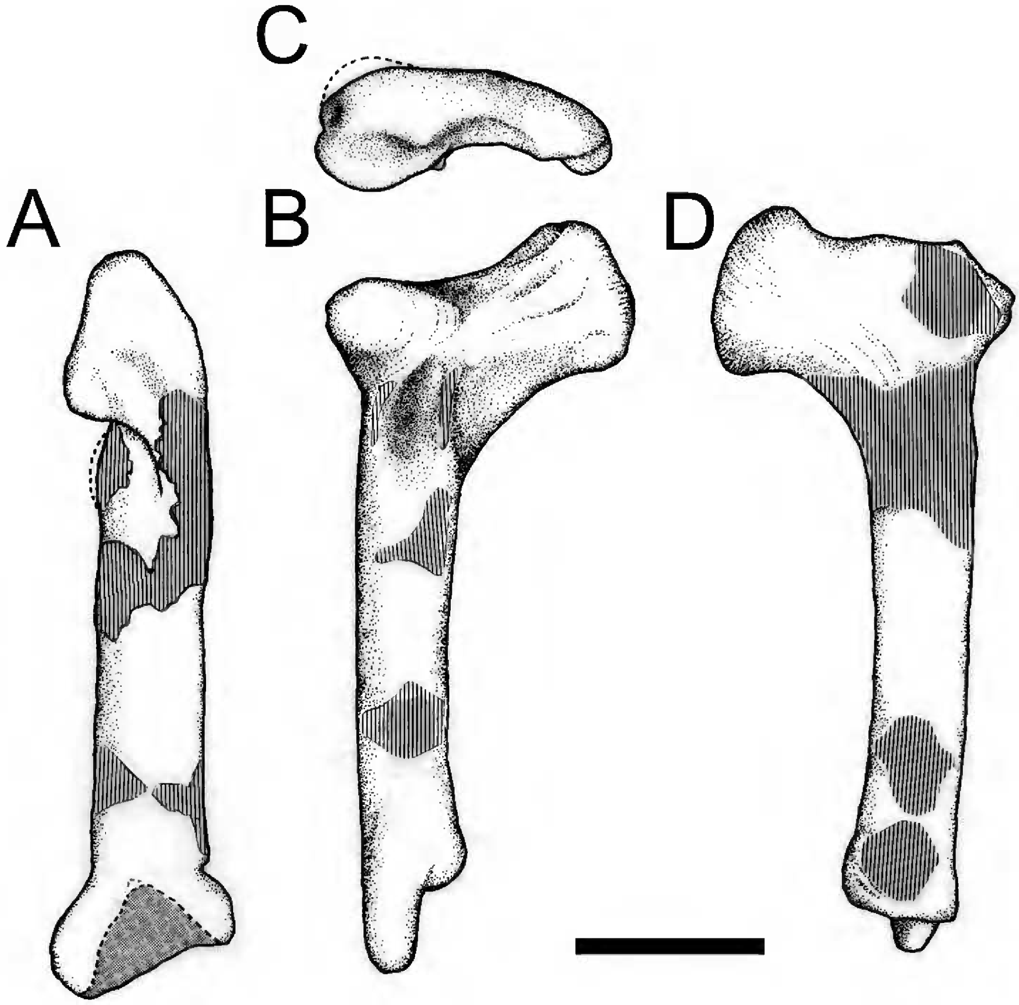

Fig.3- *Pycnonemosaurus nevesi* sp.nov. (DGM 859-R), right tibia in anterior (A), lateral (B), dorsal (C) and posterior (D) views. Scale bar: 200mm.

FIBULA (Fig.4A-D). Only the distal articulation of the right fibula is preserved (proximodistal length: 275mm). Despite its incompleteness, it is evident that this bone is much more slender than the tibia (maximum circumference: 140mm; corresponding part of tibia: 370mm). On the mediolateral edge, close to the distal articulation, the fibula has a crest-like protuberance. The lateromedial width (92mm) of the distal articulation is almost twice as large than the anteroposterior length (54mm).

Comparisons with other abelisaurs are limited because of its incompleteness and because this bone is only known in *Xenatarsosaurus* (MARTÍNEZ *et al.*, 1986). Although *Aucasaurus* has a complete fibula (CORIA, CHIAPPE, & DINGUS, 2002), it is not described or figured in detail to allow comparisons. In all three the fibula has a much smaller shaft than that of the tibia; whether or not *Xenatarsosaurus* and *Aucasaurus* also have a crest-like medial protuberance on the distal end like the one observed in *Pycnonemosaurus* is not known.

Besides the elements described here, the catalog of the MCT listed for this specimen (DGM 859-R) the distal portion of a scapula, one metatarsal and one large ungual. None of the incomplete remaining bones, however, fit these identifications; whether they were lost or if were misidentified cannot be ascertained at this time.

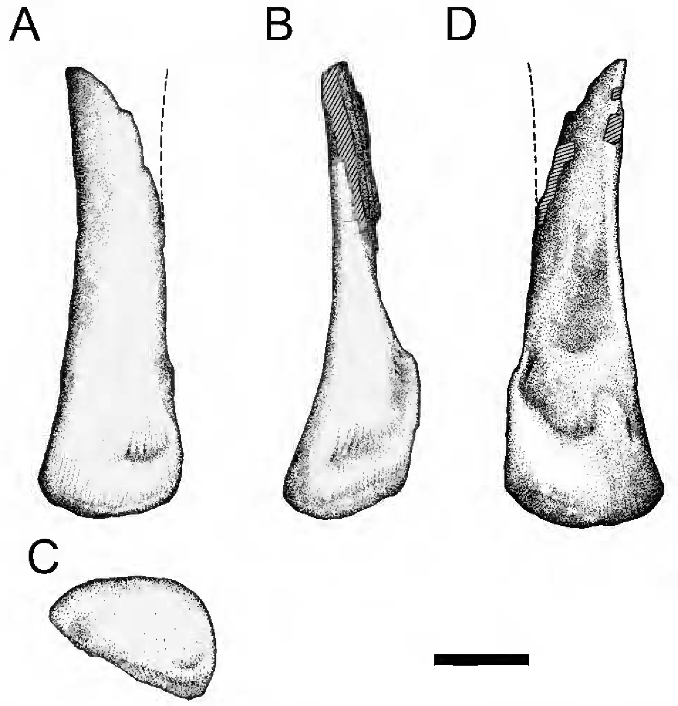

Fig.4- *Pycnonemosaurus nevesi* sp.nov. (DGM 859-R), distal end of the right fibula in lateral (A), anterior (B), distal (C) and posterior (D) views. Scale bar: 200mm.

DISCUSSION

Theropod material in Brazil is extremely rare. Besides teeth and footprints, only three taxa from Cretaceous strata have been described (two spinosaurids and one maniraptoriform), all from the Aptian-Albian layers of the Santana Formation (Romualdo Member) of the Araripe Basin (for a review see KELLNER & CAMPOS, 2000b). *Pycnonemosaurus nevesi* is the first theropod from the Paraná Basin (or Bauru Basin, see FERNANDES & COIMBRA [1996]) to be formally described.

The phylogenetic position of *Pycnonemosaurus nevesi* is difficult to establish, because most diagnostic characters of the main theropod groups reside in the skull (*e.g.*, SERENO, 1999). Although this is also the case for the abelisaurs (*e.g.,* NOVAS, 1997), *Pycnonemosaurus nevesi* is referred to this clade based on the caudal transverse processes that have anteriorly expanded distal ends, a feature reported in *Carnotaurus*, *Ilokelesia* and *Aucasaurus*, suggesting that it is an abelisaur synapomorphy (CORIA & SALGADO, 1998). As in *Carnotaurus*, the pubis of *Pycnonemosaurus* is straight (condition also observed in *Sinraptor* and *Giganotosaurus*). Both taxa have a small pubic foot (smallest in *Pycnonemosaurus*), that are still more expanded than in the Ceratosauria (*sensu* ROWE & GAUTHIER, 1990). *Pycnonemosaurus* has the anterior expansion of the pubic foot only moderately larger than the posterior, differing from most Tetanuran theropods where the posterior expansion is well developed (*e.g.*, *Allosaurus*, *Acrocanthosaurus*, *Giganotosaurus*, and the Tyrannosauridae). Furthermore, this Brazilian theropod lacks at least one Tetanuran synapomophy listed in the literature (*e.g.*, HARRIS, 1998; SERENO, 1999; CURRIE & CARPENTER, 2000): the distal end of the fibula expanded more than twice the minimum width of the fibular shaft. The abelisaur *Xenotarsosaurus* also has a more robust fibula than tetanurans (condition of *Carnotaurus* is unknown and condition of *Aucasaurus* was not reported).

Other features present in *Pycnonemosaurus* are difficult to evaluate. Although the astragalus in this new taxon is not preserved, the contact surface for the ascending process of this bone can be observed at the anterior face of the tibia, indicating that it occupied about 19% of the tibial length. This condition is similar to some tetanurans like *Allosaurus* and *Giganotosaurus* but distinct from *Sinraptor* (where this process is smaller) and from the Dromeosauridae (where this process is much taller). The condition in abelisaurs is unknown. In

Xenotarsosaurus, the extension of this process cannot be ascertained at this time (MARTÍNEZ *et al.*, 1986: fig.4B). In proximal view, the distal end of the tibia of *Pycnonemosaurus* is very similar to that of *Giganotosaurus* (Kellner, pers. observ.), with the ventral edge inclined to the same degree in respect to the horizontal plane (20-25°). The basal tetanuran *Torvosaurus* shows also a similar inclination, but here the whole distal portion of the tibia flares lateromedially (BRITT, 1991). These features are presently regarded to have been developed independently in these taxa.

To date, the Abelisauria comprise the following taxa, all monospecific: *Abelisaurus comahuensis* from the Allen Formation (Campanian), Rio Negro, Argentina (BONAPARTE & NOVAS, 1985); *Carnotaurus sastrei* from the La Colonia Formation (Late Cretaceous), Chubut, Argentina (BONAPARTE 1985; BONAPARTE, NOVAS & CORIA, 1990); *Xenotarsosaurus bonapartei* from the Bajo Barreal Formation (Late Cretaceous), Chubut, Argentina (MARTÍNEZ *et al.*, 1986); *Llokelesia aguadagrandensis* from the Rio Limay Formation (Albian-Cenomanian), Neuquén, Argentina (CORIA & SALGADO, 1998); *Aucasaurus garridoi* from the Río Colorado Formation (Campanian), Neuquén, Argentina;

Majungatholus atopus from the Late Cretaceous (?Campanian) of Madagascar (SUES & TAQUET, 1979; SAMPSON *et al.*, 1998); *Indosaurus matleyi* and *Indosuchus raptorius*, both from the Late Cretaceous Lameta Group, India (HUENE & MATLEY, 1933; BONAPARTE & NOVAS, 1985; MOLNAR, 1990). Some authors also include the poorly known Argentinean taxa *Noasaurus leali* Bonaparte & Powell, 1980 from the Lecho Formation (Maastrichtian), Salta and *Ligabueino andesi* from the La Amarga Formation (Neocomian), Neuquén in this group (*e.g.*, CORIA & SALGADO, 1998). From those, only five have published postcranial bones that can be compared with *Pycnonemosaurus*: *Carnotaurus sastrei* (caudals, proximal articulation of tibia, pubis), *Xenotarsosaurus bonapartei* (tibia), *Llokelesia aguadagrandensis* (caudals), *Aucasaurus garridoi* (caudals, tibia, fibula, pubis) and *Ligabueino andesi* (one caudal). Based on the expanded cnemial crest, *Quilmesaurus curriei* is tentatively referred to this theropod clade.

Despite the incompleteness of the new taxon, *Pycnonemosaurus* differs from *Carnotaurus* and *Xenotarsosaurus* by having a hatchet-shaped cnemial crest. *Aucasaurus* has a subquadrangular cnemial crest and does not show the expanded degree found in *Pycnonemosaurus*. Despite also having an expanded distal end of the cnemial crest the one of *Quilmesaurus curriei* differs from the new Brazilian form by being hook-shaped, with the anteroventral part remarkably expanded. *Pycnonemosaurus* also differs from *Carnotaurus*, *Llokelesia* and *Aucasaurus* by having caudals with less distally expanded transverse processes. The only caudal known from *Ligabueino* which is also supposed to be a member of the Abelisauria (*e.g.*, CORIA & SALGADO, 1998) is completely different from *Pycnonemosaurus* (and from all other abelisaurs). Lastly, *Pycnonemosaurus* has the smallest pubic foot (particularly the posterior end) of all other abelisaurs where this bone is known (*i.e.*, *Carnotaurus* and *Aucasaurus*).

Until now, no confirmed occurrence of Abelisauria has been recorded in Brazil. BERTINI (1996) referred an isolated tooth and a fragmentary premaxilla from outcrops of the Adamantina Formation (Bauru Group, São Paulo) to the Abelisauridae. Although the presence of abelisaurs in this region is possible, those specimens lack any diagnostic features that could substantiate this claim. This author further speculated that DGM 859-R (which is described here) belonged to the Abelisauridae (although mistakenly presenting a completely different locality). Indeed, based on current knowledge, *Pycnonemosaurus nevesi* is most likely referable to this clade, and is the first abelisaurid theropod recorded from Brazil to date. Based on the tibia, this taxon represented an animal between 6 to 7 meters in length.

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